

# Memo

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To: CCB

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Date: March 6, 1998

Subject: PIDC 6.0: Event characterization

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CC:

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## Abstract

This memo **recommends** installation of the event characterization volume of PIDC 6.0 into Operations. This release consists of the existing event characterization volume of PIDC 5.0 as well as all new development over the last 8 months. Three new event characterization parameters (third moment of frequency, time-frequency parameters and first-motion) have been developed, and the regional phase time domain amplitude calculations have been extended to make measurements in two new frequency bands and amplitude calculations made for analyst reviewed arrivals. The libraries, par files and Scheme code for calculation of these parameters are incorporated in this release. Two new database tables (**tf** and **tmf**) have been described and are required to be built into the appropriate database account(s).

In general, all parameters are seismologically consistent. However problems have been found with the extended QC process. It is **recommended** that this be turned off, as it is not clear what effect it has on the seismological consistency of the measurements. It is **highly recommended** that the extended QC routine be thoroughly investigated and fixed, to an end of improving the seismological consistency of the measurements.

Although the algorithm for calculating first-motion works properly, the first-motion measurements are unreliable as many of the analyst picks do not match the actual onset. It has been left to the CCB to make a decision on whether first-motion should be implemented into Operations at this time.

## Statement of Objective

PIDC 6.0 is a full release containing all development and maintenance since April, 1997 on the application software of the time-series monitoring system, data services and utilities of the proto-

type IDC. This proposal has been divided into seven volumes following the structure of the software configuration model (Farrell, 1997).

The objective of this proposal volume is to implement into Operations PIDC 6.0 event characterization measurements (CSCI 1) which includes 3 new event characterization parameters and additional regional phase time-domain amplitude measurements. Other proposal volumes discuss other software components of PIDC 6.0.

## Summary of Proposed Change

Infrastructure changes that are common to all of PIDC 6.0 are described by Beall et al. (1998). Appendix A enumerates the software modules covered by this memo.

Changes proposed here that are specific to event characterization are:

- Updated Scheme code to make all event characterization measurements
- New libtf library and extensions to the libfs library
- Several new par files and a number of additions to existing par files
- Two new database tables: **tf** and **tmf**
- Turning off extended QC

Full details of the configuration and run-time files for this upgrade are described in Appendix C, and the new database schema in Appendix D.

## Expected Benefits

General benefits of PIDC 6.0 are described by Beall et al. (1998). Specific benefits to event characterization are a reorganisation of the DFX Scheme code to make processing more efficient and the introduction of 3 new event characterization parameters:

- Third moment of frequency
- Time-frequency parameters
- First-motion

Also additional regional phase time-domain amplitude calculations will give measurements at higher frequency amplitude measurements for analyst picked arrivals.

Inclusion of these parameters into routine PIDC processing will allow the effectiveness of these parameters to be evaluated by authorised users of the PIDC for a wide range of source types and recording stations.

Turning off extended QC will allow for the measurements to be reproduced no matter what velocity model or travel time routines are used, and should provide more consistent event characterization measurements.

Memory errors that were a problem in DFX 5.0 have been fixed in this release, hence a greater percentage of measurements will be made.

## **Possible Risks and Dependencies**

There is a risk (under no extended QC conditions) that the event characterization measurements will be in error as certain spikes and noise bursts will not have been masked out. Also there is a risk that the parameters have been mis-calculated owing to errors in software or in the definition of the parameters.

In terms of running the calculations, there are no problems with the process being too CPU intensive or failing to complete.

## **Summary of Testing**

The event characterization process of DFX was tested on the Testbed for the period January 4 - 20, 1998. There were 870 events in the REB for this period. Thorough details of the testing and validation of the parameters can be found in Appendix B.

Apart from several failures of the process early on due to time constraints placed on the running time, the process has not faltered and is not CPU intensive. It takes on average about 1.5 hours to calculate all event characterization measurements for a day.

In terms of the validation of the measurements, the three new parameters and extensions were found to be seismologically consistent and of some value for future event screening methodologies. It was found that a significant proportion of measurements of the current parameters on the Testbed did not match the Ops measurements, and this was due to problems with the extended QC process. However it is believed that the removal of the extended QC process will provide more consistent measurements, and upon implementation will be an improvement to current Operations.

## **Schedule and Plan for Implementation**

There has been a last minute modification to the libfs library, tmf, par file and **tmf** table, to account for the inclusion of the variable tmfpct. This needs to be included in the testbed before it is put in Ops. The patch was delivered during the week of March 9-13.

This proposal should be implemented with automatic and interactive processing (Beall et al; 1998; Gault et al., 1998). It should be implemented with the other CSCI's or as soon as possible.

## **Costs and Resources Required for Implementation**

It is estimated that 1 man day of Operations will be required for implementation of this proposal. No additional costs will be incurred.

## References

Beall, G. et al., PIDC 6.0: Automatic processing of seismic and hydroacoustic data, Proposal to the PIDC Configuration Control Board, CCB-PRO-98/06, 1998.

Gault, A., M. Skov, J. Wang and D. Buonassisi, PIDC 6.0: Interactive Processing of Seismic and Hydroacoustic Data, Proposal to the PIDC Configuration Control Board, CCB-PRO-98/05, 1998.

Farrell, W.E, Issue 2 of the PIDC Software Architecture Description, Internal Memo, July 30, 1997

## Appendix A: Software components covered in this volume

Table 1 shows the software components that are included in this proposal volume. Other components listed in Table 1 are either included in other proposal volumes (excluded), obsoleted (as noted) or not part of PIDC 6.0 (as noted).

**Table 1: PIDC Computer Software Components**

CSCI/CSC		INCLUDED	KLOC (BYTES)	POINT OF CONTACT
<b>1. Automatic Processing</b>				
1.1	Time-series Station Processing			
1.1.1	DFX			
1.1.2	libsrc/libamp	yes	57.3	Wahl
1.1.3	libsrc/libcomplexity	yes	8.7	Jepsen
1.1.4	libsrc/libfs	yes	48.0	Wahl/Jepsen
1.1.5	libsrc/libsplp	yes	13.4	Jepsen
1.1.6	libsrc/libtf	yes	8.5	Jepsen

## Appendix B: Validation of Event Characterization Parameter Measurements

In this appendix, details on the performance of calculating event characterization measurements on the Testbed, and the seismological evaluation of both existing and new parameter measurements are described.

### 1. Testbed Performance

The event characterization process of DFX is run on six networks of stations, and it is run for six 4-hour intervals each day. During the period Jan 4-20 1998, the combined processing took about 900 seconds to complete a four-hour interval, and so on average about 1.5 hours to complete a 24 hour period. The actual processing time for each 24 hour period varied, and depended on the number of events in that day.

There have been no “crashes” of event characterization processing due to memory/coding problems since the installation of PIDC 6.0. The last fatal exit was January 11, due to speed concerns. Since the installation of the optimized DFX, there have been no problems with the completion of the processing.

### 2. Validation of existing event characterization parameter measurements

Five event characterization parameters are currently being calculated by Operations. They are, regional phase time domain amplitudes, teleseismic complexity, spectral variance, short-period to long-period ratio, and cepstral amplitudes and quefrequencies. The measurements in Operations have been compared to the corresponding measurements calculated on the Testbed. Although the distributions of the testbed measurements, shown in Figure 1, fall within the expected ranges, a great number of them do not match their corresponding Ops measurements. Table 1 lists the number of measurements for each parameter that fall within certain percentages of the Ops measurements, during the period Jan 4-20 1998.

category	regional amplitudes	splp	spectral variance	cepstral parameters	complexity
no. measurements (#m)	11218	43	281	265	4217
#m within 0.1%	9723	38	215	203	3822
#m within range 0.1-1.0%	43	2	19	0	175
#m within range 1-5%	234	2	18	0	130
#m within range 5-10%	339	0	4	27	46
#m within range 10-50%	733	1	24	8	31
#m within range 50-100%	100	0	10	15	8
#m greater than 100%	46	0	1	12	5

**Table 1:** Comparison of event-characterization parameters

It is obvious that a significant number of measurements differ, and in some cases quite dramatically. After extensive investigation of the code and testing, several reasons for the discrepancies were discovered. Most were due to algorithmic differences, and some due to data differences. The following are the major causes:

- The extended QC process is performed using statistics in small, overlapping, sequential windows, and these statistics are dependent on the data used to compute them. Introduction of more accurate travel time routines led to a change (between DFX 5.0 and DFX 6.0) in the start/end times of the data window used to encompass all subsequent event characterization measurements for a given run. Because the extended QC is applied to this overall window, these changes in start/end times led to different QC results because of the difference in statistics resulting from the QC processing. For example, the threshold for declaring points spikes in DFX 6.0 may have been exceeded, whereas the threshold may not have been exceeded in DFX 5.0 (e.g. 19.9 versus 20.1 as the threshold). It is believed that this is the major reason for the discrepancies.

**Test runs turning off extended QC or increasing thresholds significantly (in the limit this turns off extended QC) gave consistent results between DFX 5.0 and 6.0 for the same input data set.**

- It was found upon re-running some intervals using the DFX 6.0 executable with the Ops archive data that there were no differences found. This points out that there are differences between the data on the Testbed and data on Ops. It is not known at this stage what percentage of discrepancies were due to this problem, but it is not believed to be a large percentage.
- There was a bug found in the QC fixing routine for the case where two points out of three were found to be “bad”. The interpolation routine was including the second bad point in the fix for the first bad point. Only one instance of this situation was actually found, but it is believed that this may have exacerbated the largest discrepancies caused by the use of extended QC. Indeed, this was the reason for the largest amplitude discrepancy found.

**A patch release of DFX (PIDC 6.0.37) was installed on the testbed on 26 Feb 1998, to fix this problem.**

In conclusion, extended QC is causing problems with reproducibility of measurements under shifts in the time window. However, it is not clear what effect it has on the seismological consistency of the measurements. Consequently, extended QC has been turned off for event characterization processing on the testbed. It will remain in this state until further tuning can be done or algorithmic modifications can be made to extended QC.

### **3. Validation of new event characterization parameter measurements**

There are three new event characterization parameters (third moment of frequency, time-frequency parameters and first motion), and extensions to the regional phase time-domain amplitude measurements in PIDC\_6.0. Below the requirement, method of computation and seismological evaluation for each parameter are described.

#### 3.1 Third Moment of Frequency of P-wave

### *Requirement*

The source spectrum of the various source types vary to some degree, with nuclear-explosion sources having higher frequency content than equivalent sized earthquakes. The third moment of frequency measure will be employed to find these differences, and so assist with event screening.

### *Method of Computation*

The TMF measure follows that of Wiechart (1971) and is calculated as

$$\text{TMF} = \left( \int_{f_{\min}}^{f_{\max}} f^3 \text{sig}(f) df / \int_{f_{\min}}^{f_{\max}} f^3 \text{sig}(f) df \right)^{1/3}$$

where the signal has been corrected for noise (i.e.  $\text{sig}(f) = \text{signal}(f) - 0.5 * (N_1(f) + N_2(f))$ ).  $N_1(f)$  and  $N_2(f)$  are two distinct noise spectrums made before the start of the signal. This measure gives more weight to high frequencies, so events with a greater proportion of high frequency energy will have higher TMF values. Typically  $f_{\min}$  and  $f_{\max}$  are set to 0 and 5 Hz respectively. At the PIDC,  $f_{\min}$  and  $f_{\max}$  have been tuned and are set to 0.5 and 5.0 Hz. TMF measurements are made for all associated P phases greater than 20 degrees, and only those that have a percentage exceeding *tmf-percent* (default = 90%) of the signal spectrum amplitudes greater than corresponding noise spectrum amplitudes, are stored in table *tmf*. The latter restriction is to provide some quality control of the measurements.

### *Seismological Evaluation*

The Testbed results of TMF versus mb in Figure 2, show that TMF measurements are well constrained and in general decrease with magnitude. This is consistent with the fact that the cut-off frequency of the source spectrum decreases with magnitude. The TMF versus mb plots in Figure 2 of the Chinese earthquakes near the Lop Nor test site and nuclear explosions at 4 stations in the current primary IMS network, indicate that there is some separation between the tmf values of earthquakes and nuclear explosions. In these cases the nuclear explosions generally have higher TMF values than the earthquakes at equivalent magnitudes. However, it must be noted that the capability of TMF will be regionally dependent and will need to be evaluated in due course.

## 3.2 Time-Frequency Parameters

### *Requirement*

Waveforms produced by multiple source events (e.g. ripple-fired mining blasts) commonly show spectral modulations and often the modulations extend well into the coda. Time-frequency parameters (2-D cepstral peaks and correlation measurements) are calculated using the Hedlin et al. (1989,1990) multi-taper sonogram technique to detect these delayed-fired diagnostics.



### *Method of Computation*

The calculation involves converting the time series (first 30s of coda) into a time-frequency (t-f) matrix. After converting the matrix to a binary form and randomising all points that fall below the noise level, an estimate of how well the t-f matrix is correlated in time is made. The max amplitude and associated quefrequency of the 2D Fourier transform of the t-f matrix is determined, and the zero-lag cross-correlation between the 3 pairs of t-f matrices (for 3-component stations only) is estimated. T-f measurements are made for all associated stations less than 15 degrees and are stored in table **tf**.

### *Seismological Evaluation*

The distribution of the three key TF parameters calculated by PIDC\_6.0 DFX on the Testbed are shown in Figure 3a. The measurements are well constrained, ranging from 100 to 1900 for the average vertical 2-D cepstrum maximum (zavcep), from 0.1 to 1.3 for the average vertical auto-correlation (zavcor), and 0.1 to 0.9 for the zero cross-correlation (xcor). TF measurements of a set of quarry blasts and earthquakes (events 1-25 of the CSS Ground-Truth Database), at station GERES, are shown in Figure 3b. The plot indicates that the two different source types separate well.

Although the contractor, Michael Hedlin (pers. comm.) has pointed out that the time frequency parameters may only be useful for discrimination out to a distance of 5 degrees, it has been proposed that these parameters be measured for all events out to 15 degrees, in order to determine the actual capability and regional variability of these parameters.

## 3.3 First Motion

### *Requirement*

Nuclear explosion sources are compressional, so the first motion is always upwards, whereas earthquakes, which can be described by a double couple, will display upward or downward first-motion that will be dependent on the source-receiver geometry. If this parameter can be calculated and employed successfully, it would greatly improve the event screening capability.

### *Method of Computation*

First motion is calculated for the first arriving phase of each associated waveform, and is restricted to phases Pn, Pg, P and PKP. It is determined from the filtered (0.5-5.0 Hz) beam by finding the first maximum or minimum after the measured onset time of the arrival. The signed amplitude of this turning point is returned as the measure of first motion and is stored in the database table **amplitude**.

### *Seismological Evaluation*

A brief evaluation of first motion measurements was undertaken using data from the Australian array Warramunga (WRA). Data from this station was extracted to check the results of first

motion measurements made on the test bed for days January 14, 16 and 18 1998. This data was examined by an analyst who determined, if possible, the first motion.

For this period 122 first motions were measured at WRA, of these 89 were classified as being emergent by the analyst. Of the remaining measurements the analyst agreed with the automatic measurement 21 times and disagreed 12 times.

The first-motion algorithm searches for the first maxima or minima after the onset and in all cases observed the program delivered a measure consistent with this algorithm (ie. the program works). The differences between measured and observed motions arose from differences in onset time. Two examples are shown in Figure 4a and b of incorrectly picked onsets which lead to a disagreement between analyst and the testbed on the first motion signature. In Figure 4c, the success of the first-motion measurements, as determined by an analyst, is plotted against the signal to noise ratio taken from the arrival file. The figure indicates that many emergent events have low signal to noise ratio. It also shows that the impulsive events that the analyst disagreed with span a range of signal to noise ratios, so the thought of screening first motion by SNR is not possible at this stage.

In summary, the program to calculate first-motion signature works, but the seismological validity of these measurements cannot be rated as high. Further work needs to be done to improve the rate of success of the first motion measurement by either improving onset picks or improving the sophistication of the algorithm to attend to aberrant onsets.

### 3.4 Additional regional phase time-domain amplitude measurements

#### *Requirement*

At the Event Screening Conference in Beijing, China, it was recommended that regional phase time-domain amplitude measurements should be extended to higher frequencies. Also, since existing amplitude measurements are calculated within theoretical origin-based time windows, it has been pointed out that amplitude measurements based on analyst arrival picks would be more accurate.

#### *Method of Computation*

Origin-based amplitude measurements in the 10-12 and 12-14Hz frequency bands are calculated in the same way as in the lower frequency bands (see CCB-960702 for details). Arrival based amplitude measurements are made as follows:

Absolute maximum amplitude on 2-4, 4-6, 6-8, 8-10, 10-12, 12-14 rms beams for standard signal and noise windows around Pn, Pg, Sn & Lg phases. The signal and noise windows are:

```
signal - 5 seconds before, to 15 seconds after onset
noise   - 15 seconds before, to 5 seconds before onset
```

## Seismological Evaluation

Origin-based amplitude measurements for all 4 regional phases in the 10-12 and 12-14Hz frequency bands are shown in Figure 5. Although there aren't many measurements, they appear to be seismologically consistent as they are starting to show similar trends to those outlined in CCB-960702. That is, amplitude decreases with distance, rate of decrease differs with both frequency and phase, and attenuation is greater at higher frequencies and Sn and Lg attenuate faster than Pn.

Figure 6 shows the predicted time windows used in calculating the origin-based amplitude measurements and the actual analyst picks for station MOX in the period September 1995-May 1997. It is clear from the figure that the onset of some Pn and Pg arrivals occur after the end of the predicted time windows. Although this is expected at distances < 3 degrees, as the predicted time windows don't work well (this will be addressed in a future CCB proposal), other outliers mean that their measurements are inaccurate as they are calculated on the later part of the arrival's coda.

A quick analysis of the Testbed database indicates that about 10% of the arrival-based amplitude measurements have a SNR twice that of the corresponding origin-based measurements (see Table 2). The arrival-based amplitude measurements in conjunction with origin-based amplitude measurements of regional phases not picked by the analysts, will provide a far superior set of amplitude measurements for event screening.

phase	chan	no. measurements	no. measurements with >2 SNR improvement
Pn	rms2-4	383	43
Sn	rms2-4	102	10
Pg	rms2-4	55	8
Lg	rms2-4	75	2

**Table 2:** Number of rms2-4 amplitude measurements with >2 SNR improvement for each regional phase. The data span the period January 4-20, 1998 of the Testbed database.

## References

- CCB-960702: To incorporate routine estimation of event characterization parameters into IDC operations, CCB Memo, July 1996.
- Grant L., Coyne J. & Ryall, F. (1993). CSS Ground-Truth Database: Version 1 Handbook, Technical Report C93-05.
- Hedlin, M. A. H., Minster, J. B. & Orcutt, J. A. (1989). The time-frequency characteristics of quarry blasts and calibration explosions recorded in Kazakhstan, U.S.S.R., *Geophys. J. Int.*, **99**, 109-121.

Hedlin, M. A. H., Minster, J. B. & Orcutt, J. A. (1990). An automatic means to discriminate between earthquakes and quarry blasts, *Bull. Seis. Soc. Am.*, **80**, 2143-2160.

Wiechart, D. H. (1971). Short period spectral discriminant for earthquake and explosion differentiation, *Z Geophys*, **37**, 147-152.

## Appendix C: Configuration and “run-time” files

In the upgrade from PIDC\_5.0 to PIDC\_6.0, many configuration and run-time files have been modified or added. Several new par files, a number of additions to existing par files, 2 new data-base tables and an updated Scheme code are required for the upgrade to PIDC\_6.0. The necessary changes and new files are described below.

### 1. New par files

1.1 *tf/tf.par*(required for calculation of time-frequency parameters), consists of

```
tf_adv=10.0 /* length (s) of noise window */
tf_tlen=40.0/* length (s) of total processing window (noise and signal) */
tf_tsub=2.5/* length (s) of sonograms' sub-windows */
tf_ps=20.0/* controls length(s) of offset between sonograms sub-windows*/
tf_iin=1/* units of input time-series (0-disp;1-vel;2-acc) nb set=1 */
tf_iout=1/* units of output spectra (0-disp;1-vel;2-acc) nb set=1 */
tf_tbw=4.0/* time-bandwidth product */
tf_nfb=11/* no. frequencies spanned by the broad binary filter */
tf_nfn=5/* no. frequencies spanned by the narrow binary filter */
tf_f0=0.0/* minimum frequency */

tf-nettype=$(NetType)
tf-stattype=$(StaType)
tf-bandtype1=$(BandType1)
tf-bandtype3=$(BandType3)
```

where the following rules for assigning values to BandType1 and BandType3 are :

For an array:

BandType1=bandtype of single-component sites used in array processing.

BandType3=bandtype of three-component sites (if NetSta=3c)

or BandType3=BandType1 (if NetSta=1c)

For a ss:

BandType3=BandType1=bandtype of site currently used for processing.

1.2 *tmf/tmf.par*(required for the calculation of third moment of frequency), consists of

```
tmf-fmin=0.0 /* minimum frequency for tmf measurements */
tmf-fmax=5.0 /* maximum frequency for tmf measurements */
tmf-percent=90.0 /*percentage of signal spectrum amplitudes > noise
spectrum amplitudes */
```

## 2. Additions to existing par files

### 2.1 *amp/evch-amp.par* (required for the calculation of: originbased amplitudes in 10-12 & 12-14Hz frequency bands, arrival-based amplitudes, and first motion)

#### # Amplitudes for theoretical arrivals

sigPn	Pn	intsPn	rms10-12	abs_max	-1
sigPn	Pn	intsPn	rms12-14	abs_max	-1
noiPn	Pn	intnPn	rms10-12	abs_max	-1
noiPn	Pn	intnPn	rms12-14	abs_max	-1
sigPg	Pg	intsPg	rms10-12	abs_max	-1
sigPg	Pg	intsPg	rms12-14	abs_max	-1
noiPg	Pg	intnPg	rms10-12	abs_max	-1
noiPg	Pg	intnPg	rms12-14	abs_max	-1
sigSn	Sn	intsSn	rms10-12	abs_max	-1
sigSn	Sn	intsSn	rms12-14	abs_max	-1
noiSn	Sn	intnSn	rms10-12	abs_max	-1
noiSn	Sn	intnSn	rms12-14	abs_max	-1
sigLg	Lg	intsLg	rms10-12	abs_max	-1
sigLg	Lg	intsLg	rms12-14	abs_max	-1
noiLg	Lg	intnLg	rms10-12	abs_max	-1
noiLg	Lg	intnLg	rms12-14	abs_max	-1

#### # Amplitudes for observed arrivals

sigobs	-	obs_s	rms2-4	abs_max	-1
sigobs	-	obs_s	rms4-6	abs_max	-1
sigobs	-	obs_s	rms6-8	abs_max	-1
sigobs	-	obs_s	rms8-10	abs_max	-1
sigobs	-	obs_s	rms10-12	abs_max	-1
sigobs	-	obs_s	rms12-14	abs_max	-1
noiobs	-	obs_n	rms2-4	abs_max	-1
noiobs	-	obs_n	rms4-6	abs_max	-1
noiobs	-	obs_n	rms6-8	abs_max	-1
noiobs	-	obs_n	rms8-10	abs_max	-1
noiobs	-	obs_n	rms10-12	abs_max	-1
noiobs	-	obs_n	rms12-14	abs_max	-1

#### # First motion amplitude

FmSig	-	intsFm	Fm0.5	fm	-1
FmNoi	-	intnFm	Fm0.5	rms	-1

### 2.2 *beam/evch/evch-beam.par* (required for the calculation of: originbased amplitudes in 10-12 & 12-14Hz frequency bands, arrival-based amplitudes, and first-motion)

rms10-12	rms	no	0	-1.0	0.0	0.0	-	10.0	12.0	3	0	BP	vertical
rms12-14	rms	no	0	-1.0	0.0	0.0	-	12.0	14.0	3	0	BP	vertical
Fm0.5	coh	no	0	-1	\$(fm-azi)	\$(fm-slow)	-	0.5	5.0	3	0	HP	vertical

## 2.3 DFX-evch.par

There have been many changes. Par file is now:

```
#
# DFX par file for event characterization processing
# @(#)DFX-evch.par      4.3 11/06/97
#
# The following parameters are required on the command line
# prior to setting par=<this file>: net, start-time, end-time
#
par=$(IMSPAR)

# Set up local convenience variables
dfx-par-dir=$(PARDIR)/static/DFX
dfx-scheme-dir=$(PARDIR)/static/DFX/scheme

# Database name and vendor from IMSPAR
database-vendor=$(DATABASE_VENDOR)
database-account=month/month@alfheim

# Travel time tables prefix from IMSPAR
vmodel-spec-file=$(VMSF)

# Show warnings?
verbosity=4

# Reset stderr to stdout
error-stream=stdout

# Processing mode is operational for pipeline processing
processing-mode=interactive
#processing-mode=operational

# Maximum wfdisc extension
wfdisc-extension-len=$(max-wfdisc-duration)

# Event characterization edge offset
evch-data-offset-len=15

# Time intervals to use for data access
evch-data-tirec-list=evch-reg,evch-tele

# Requirements for complexity measurements
evch-PcP-list=PcP
evch-PcP-min-delta=60.
evch-PcP-max-delta=90.
evch-complexity-phase-list=Pn,P,PKP
evch-complexity-beamrec=cmplx
evch-complexity-min-delta=30.
evch-complexity-max-delta=90.

# Requirements for splp measurements
evch-splp-max-depth=30.
evch-splp-min-delta=0.
evch-splp-max-delta=15.

# Requirements for smult measurements
evch-smult-max-depth=30.
evch-smult-min-delta=0.
evch-smult-max-delta=20.

# Requirements for originamp measurements
evch-originamp-amprec-list=sigPn,noiPn,sigPg,noiPg,sigSn,noiSn,sigLg,noiLg
```

```

evch-originamp-max-depth=30.
evch-originamp-min-delta=0.
evch-originamp-max-delta=20.

# Requirements for arrivalamp measurements
evch-arrivalamp-amprec-list=sigobs,noiobs
evch-arrivalamp-max-depth=30.
evch-arrivalamp-min-delta=0.
evch-arrivalamp-max-delta=20.

# Requirements for first motion measurements
evch-fm-phase-list=Pn,Pg,P,PKP
evch-fm-amprec-list=FmSig,FmNoi

# Requirements for time-frequency measurements
evch-tf-phase-list=Pn,Pg
evch-tf-max-depth=30.
evch-tf-min-delta=0.
evch-tf-max-delta=15.

# Requirements for third moment of frequency measurements
evch-tmf-phase-list=P,PKP
evch-tmf-min-delta=20.
evch-tmf-max-delta=180.

# This file gets loaded in scheme once we have a station to process
evch-site-recipe-file=$(dfx-par-dir)/DFX-site-evch.par

# Load the automated event processing scheme file
projfile=$(dfx-scheme-dir)/DFX-evch.scm

```

## 2.4 DFX-site-evch.par

There have been many changes. Par file is now:

```

#
# DFX event characterization site par file
# SCCSID: @(#)DFX-site-evch.par 4.4 11/06/97
#
# The following parameters are required to be set from the command line
# before using this file: IMSPAR, sta
#

# Set up par files to use, dependent on the station-descriptive pars
# NetType (array or ss), StaType (1c or 3c), and BandType (s or b)
# from station par file

# The application of qc pars is network-type specific
dfx-arrayqc=array-qc.par
dfx-ssqc=ss-qc.par

# The application of splp pars is network-, station-, and
# band-type specific
dfx-array1cssplp=null.par
dfx-array1cbsplp=null.par
dfx-array3cssplp=null.par
dfx-array3cbsplp=null.par
dfx-ss1cbsplp=null.par
dfx-ss1cssplp=null.par
dfx-ss3cbsplp=splp.par
dfx-ss3cssplp=null.par

# Read station par file for NetType, StaType
par=$(OPSDIR)/static/stations/$(sta).par

# Create default parameter file names

```



```

dfx-qc-recipe=$(dfx-$(NetType)qc)
dfx-beam-recipe=evch/evch-beam.par
dfx-amp-recipe=evch-amp.par
dfx-ti-recipe=evch-ti.par
dfx-smult-recipe=$(sta)-smult.par
dfx-splp-recipe=$(dfx-$(NetType)$(StaType)$(BandType3)splp)
dfx-complexity-recipe=complexity.par
dfx-tf-recipe=tf.par
dfx-tmf-recipe=tmf.par

# Read station par file again for any site-specific overrides
# for default parameter file names, etc.
par=$(OPSDIR)/static/stations/$(sta).par

# Load parameters
par=$(dfx-par-dir)/qc/$(dfx-qc-recipe)
par=$(dfx-par-dir)/beam/$(dfx-beam-recipe)
par=$(dfx-par-dir)/amp/$(dfx-amp-recipe)
par=$(dfx-par-dir)/ti/$(dfx-ti-recipe)
par=$(dfx-par-dir)/smult/$(dfx-smult-recipe)
par=$(dfx-par-dir)/splp/$(dfx-splp-recipe)
par=$(dfx-par-dir)/complexity/$(dfx-complexity-recipe)
par=$(dfx-par-dir)/tf/$(dfx-tf-recipe)
par=$(dfx-par-dir)/tmf/$(dfx-tmf-recipe)

```

### 3. Updated DFX-evch.scm code

DFX-evch.scm has been updated and reorganised so that three new event characterization parameters and additional amplitude measurements are calculated, and so that the code is more efficient. Also, several functions that are common to many DFX processes have been taken out and combined in DFXdefault.scm

## APPENDIX D: New Database Tables

Two new tables, **tmf** and **tf** are required for PIDC\_6.0. The structure of each table, their relations and attributes are described in detail below.

### 1. Database structure

Relation: **tmf**

Description: Third Moment of Frequency Measurement

attribute name	field no.	storage type	external format	character positions	attribute description
arid	1	i4	i8	1-8	arrival identifier
sta	2	c6	a6	10-15	station code
rectype	3	c8	a8	17-24	recipe identifier
tmf	4	f4	f7.2	26-32	third moment of frequency
tmfpct	5	f4	f7.2	34-40	percentage of signal spectrum amplitudes > noise spectrum amplitudes
lddate	6	date	a17	42-58	load date

Relation: **tf**

Description: Time-frequency measurements

attribute name	field no.	storage type	external format	character positions	attribute description
orid	1	i4	i8	1-8	origin identifier
sta	2	c6	a6	10-15	station code
rectype	3	c8	a8	17-24	recipe identifier
zavpct	4	f4	f7.2	26-32	ratio of bad points to total(vertical)
navpct	5	f4	f7.2	34-40	ratio of bad points to total (north)
eavpct	6	f4	f7.2	42-48	ratio of bad points to total (east)
xavpct	7	f4	f7.2	50-56	ratio of bad points to total (cross-correlation)
zavcep	8	f4	f7.2	58-64	average 2D cepstrum max(vertical)
navcep	9	f4	f7.2	66-70	average 2D cepstrum max (north)
eavcep	10	f4	f7.2	72-76	average 2D cepstrum max (east)
zavcor	11	f4	f7.2	78-84	average autocorrelation (vertical)
navcor	12	f4	f7.2	86-92	average autocorrelation (north)
eavcor	13	f4	f7.2	94-100	average autocorrelation (east)
xcor	14	f4	f7.2	102-108	zero cross-correlation

## 2. Database relations

Name: **tmf**  
 Keys: Primary. *arid*  
 Convenience: *sta*  
 Data: Descriptive. *rectype*  
           Measurement. *tmf, tmfpct*  
           Administrative. *lddate*  
 Description: Contains the measure of third moment of frequency and the percentage of signal frequency amplitudes greater than the corresponding noise frequency amplitudes, for an arrival identified by *arid*. The measurements are used for event screening.

Name: **tf**  
 Keys: Primary. *orid, sta*  
 Data: Descriptive. *rectype*  
           Measurement *zavpct, navpct, eavpct, xavpct, zavcep, navcep, eavcep, zavcor, navcor, eavcor, xcor*  
           Administrative. *lddate*  
 Description: Contains a number of time-frequency measurements for a given orid-station pair. The measurements are used for event screening.

## 3. Database attributes

Only the new database attributes are described.

---

Name: *rectype*  
 Relation: **tf, tmf**  
 Description: Recipe identifier. It is a term used to identify values of par parameters employed in the calculations.  
 ORACLE: VARCHAR2(8)  
 NA Value: NOT ALLOWED. A valid entry is required.  
 Range: Any string up to 8 characters long. Default setting = "default".

---

Name: *tmf*  
 Relation: **tmf**  
 Description: Third moment of frequency.  
 ORACLE: FLOAT(24)  
 NA Value: NOT ALLOWED. A valid entry is required.  
 Range: *tmf* >= 0

---

-----  
Name: tmfpct  
Relation: **tf**  
Description: Percentage of signal spectrum amplitudes greater than their corresponding noise spectrum amplitudes in the frequency range [tmf-fmin,tmf-fmax]. tmf-fmin,tmf-fmax are par parameters.  
ORACLE: FLOAT(24)  
NA Value: NOT ALLOWED. A valid entry is required.  
Range:  $0 \leq \text{tmfpct} \leq 100$   
-----

Name: zavpct  
Relation: **tf**  
Description: Average ratio of bad points to total of the vertical component traces.  
ORACLE: FLOAT(24)  
NA Value: NOT ALLOWED. A valid entry is required.  
Range:  $0 \leq \text{zavpct} \leq 1$   
-----

Name: navpct  
Relation: **tf**  
Description: Average ratio of bad points to total of the north component traces.  
ORACLE: FLOAT(24)  
NA Value: NOT ALLOWED. A valid entry is required.  
Range:  $0 \leq \text{navpct} \leq 1$   
-----

Name: eavpct  
Relation: **tf**  
Description: Average ratio of bad points to total of the east component traces.  
ORACLE: FLOAT(24)  
NA Value: NOT ALLOWED. A valid entry is required.  
Range:  $0 \leq \text{eavpct} \leq 1$   
-----

Name: xavpct  
Relation: **tf**  
Description: Average ratio of bad points to total of the cross-correlation trace.  
ORACLE: FLOAT(24)  
NA Value: NOT ALLOWED. A valid entry is required.  
Range:  $0 \leq \text{xavpct} \leq 1$   
-----

Name: zavcep  
Relation: **tf**  
Description: Average maximum value in the 2D cepstrum of the vertical component traces  
ORACLE: FLOAT(24)  
NA Value: NOT ALLOWED. A valid entry is required.  
Range:  $\text{zavcep} \geq 0$   
-----

---

Name: navcep  
 Relation: **tf**  
 Description: Average maximum value in the 2D cepstrum of the north component traces  
 ORACLE: FLOAT(24)  
 NA Value: NOT ALLOWED. A valid entry is required.  
 Range: navcep >= 0

---

Name: eavcep  
 Relation: **tf**  
 Description: Average maximum value in the 2D cepstrum of the east component traces  
 ORACLE: FLOAT(24)  
 NA Value: NOT ALLOWED. A valid entry is required.  
 Range: eavcep >= 0

---

Name: zavcor  
 Relation: **tf**  
 Description: Average autocorrelation along the time axis across all frequencies excluding randomised points of the vertical component traces.  
 ORACLE: FLOAT(24)  
 NA Value: NOT ALLOWED. A valid entry is required.  
 Range: zavcor >= 0

---

Name: navcor  
 Relation: **tf**  
 Description: Average autocorrelation along the time axis across all frequencies excluding randomised points of the north component traces.  
 ORACLE: FLOAT(24)  
 NA Value: NOT ALLOWED. A valid entry is required.  
 Range: navcor >= 0

---

Name: eavcor  
 Relation: **tf**  
 Description: Average autocorrelation along the time axis across all frequencies excluding randomised points of the east component traces.  
 ORACLE: FLOAT(24)  
 NA Value: NOT ALLOWED. A valid entry is required.  
 Range: eavcor >= 0

---

Name: xcor  
 Relation: **tf**  
 Description: zero cross-correlation between the 3 pairs of t-f matrices.  
 ORACLE: FLOAT(24)  
 NA Value: NOT ALLOWED. A valid entry is required.  
 Range: xcor >= 0

---

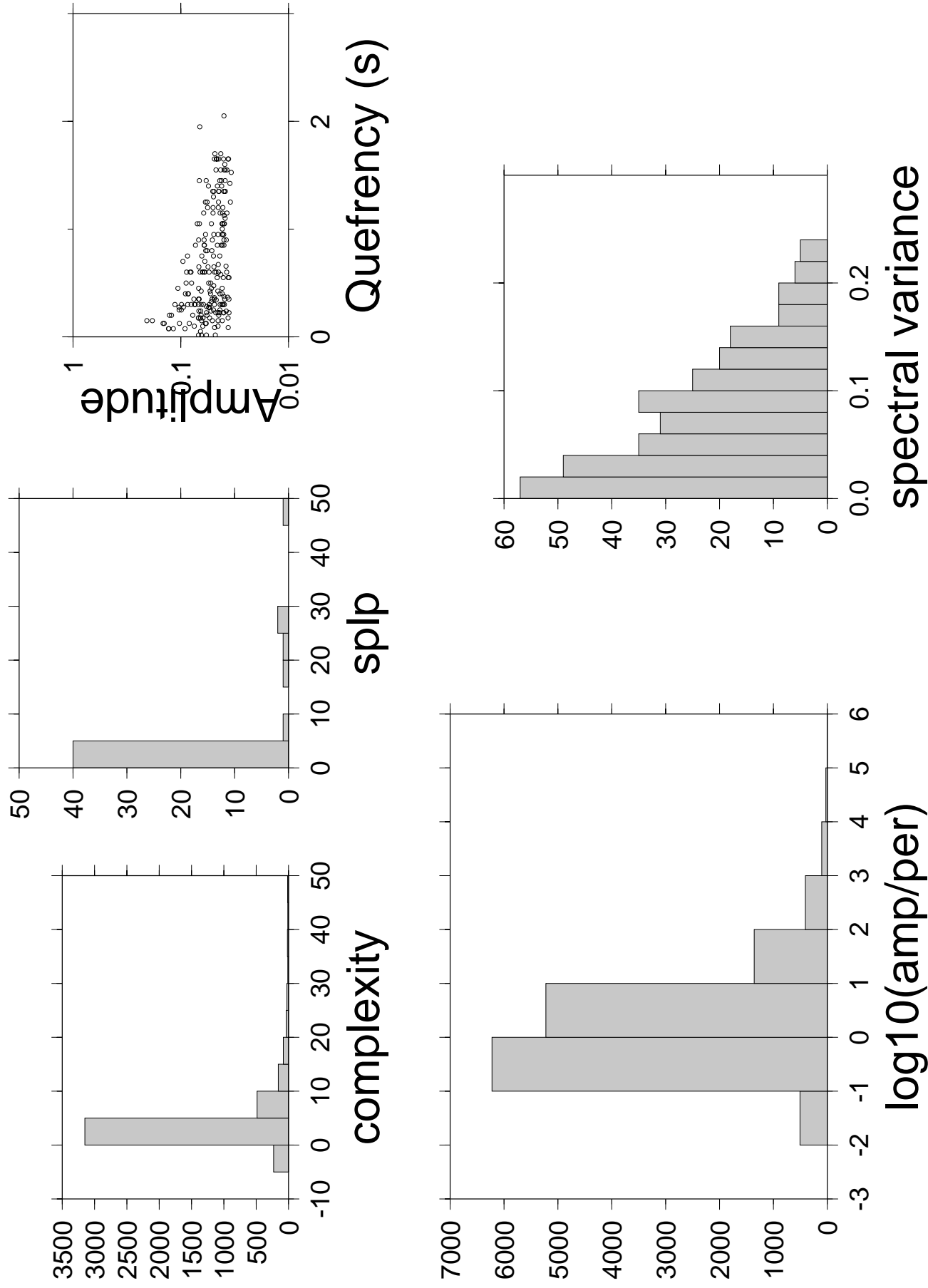
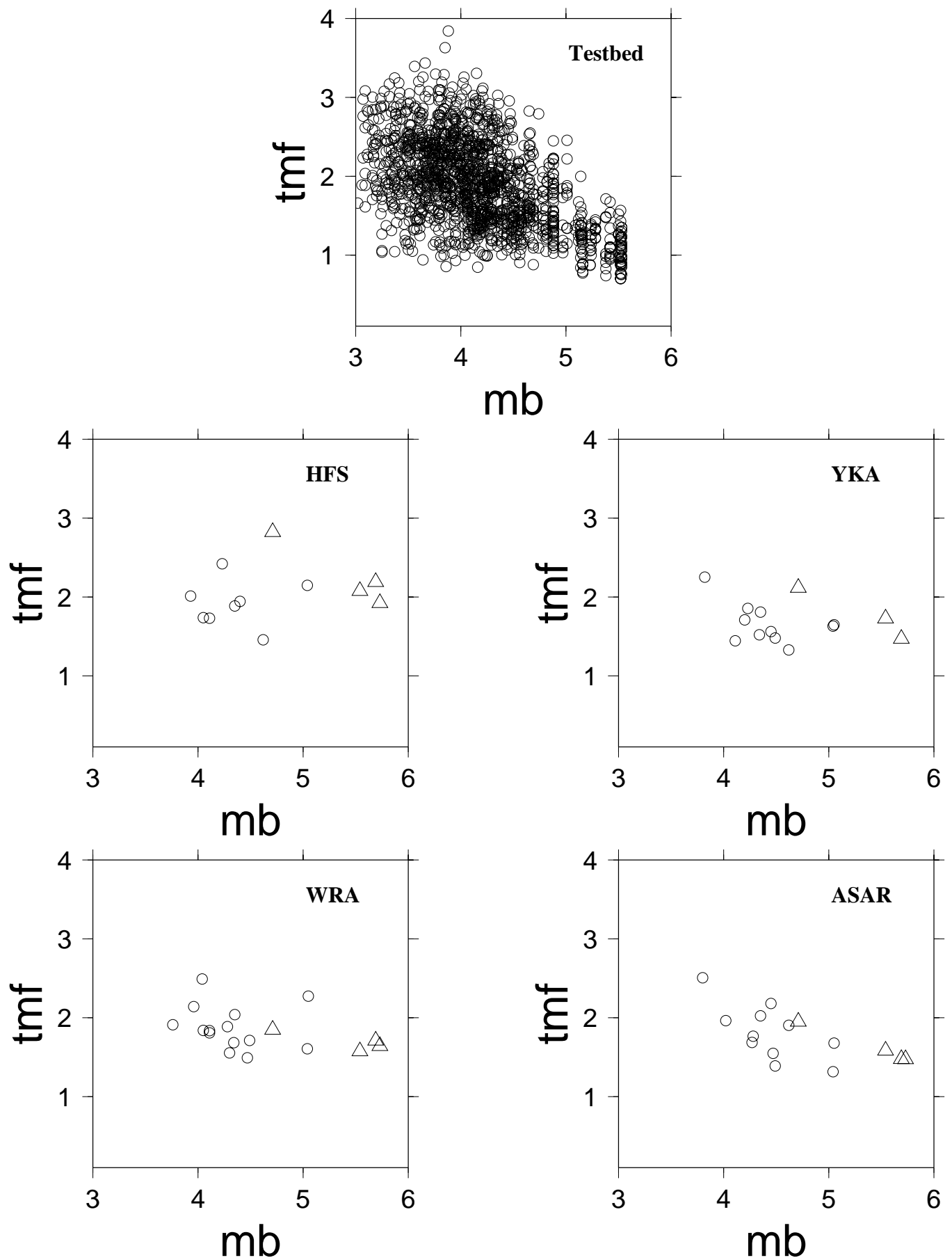
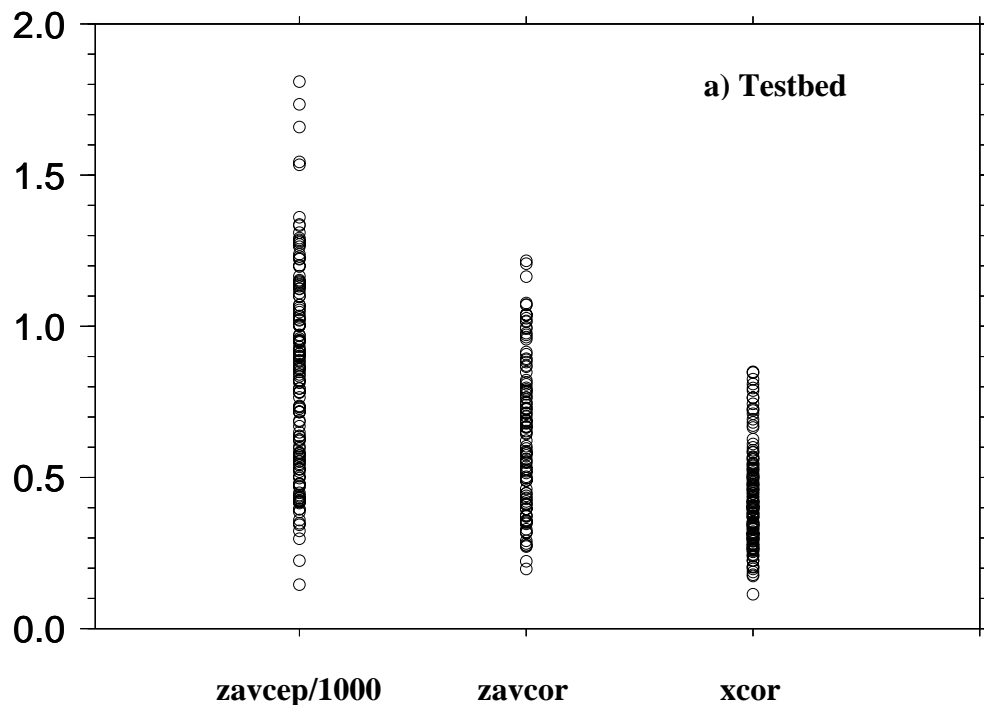
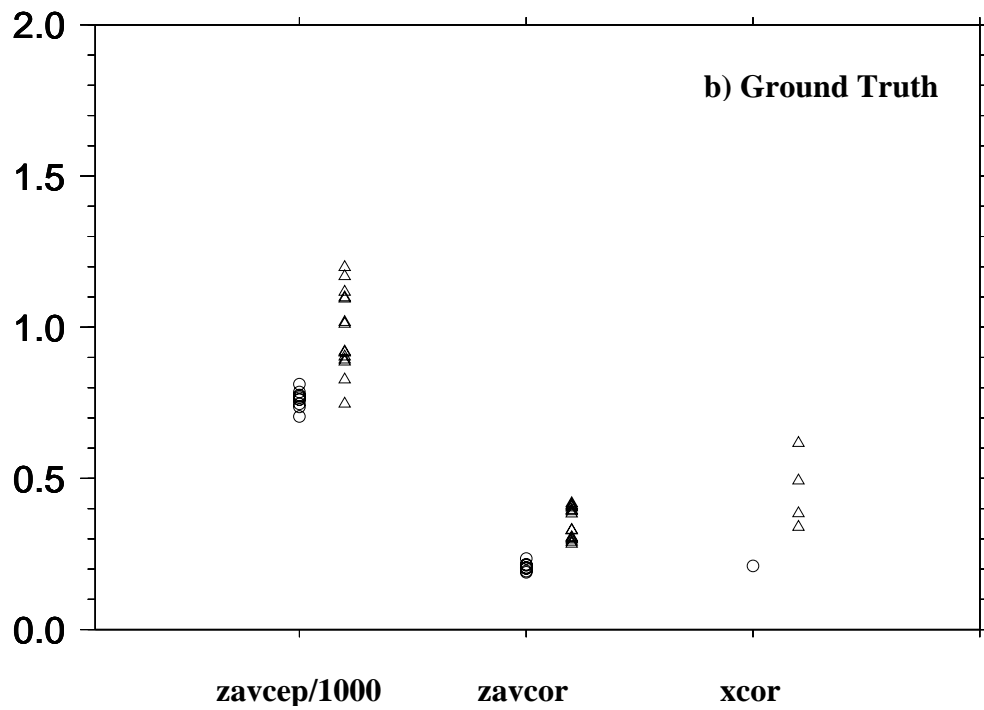


Figure 1: Distributions of origin-based amplitudes, spectral variance, complexity, short-period/long-period ratio and cepstral parameters, calculated by PIDC\_6.0 DFX on the Testbed. The data span the period: Jan 4 - Jan 20, 1998.

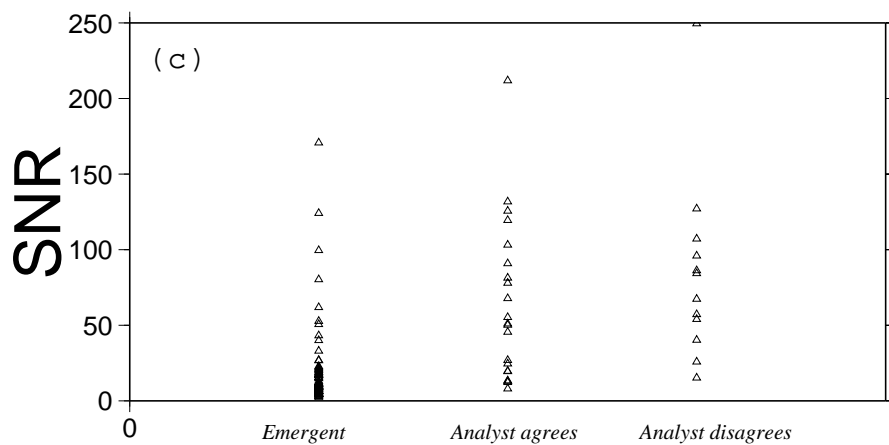
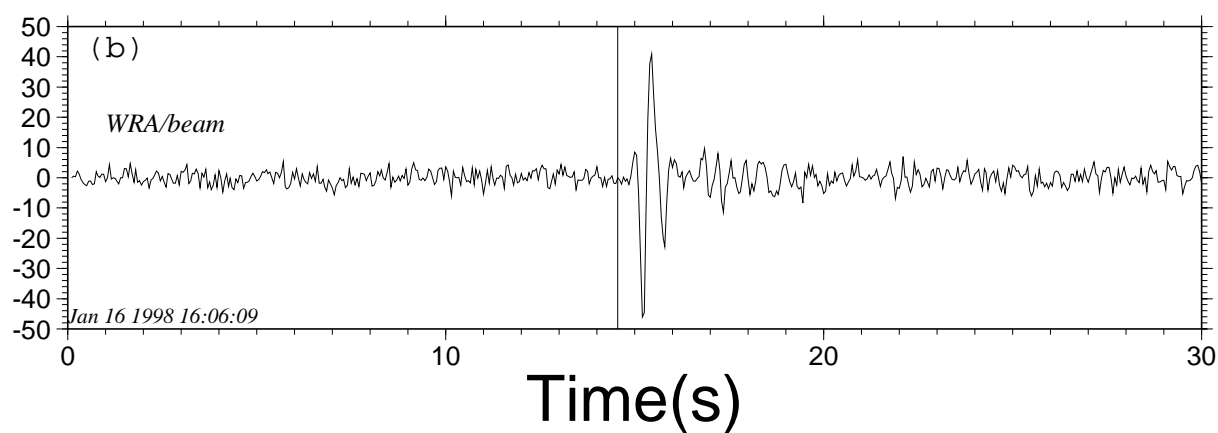
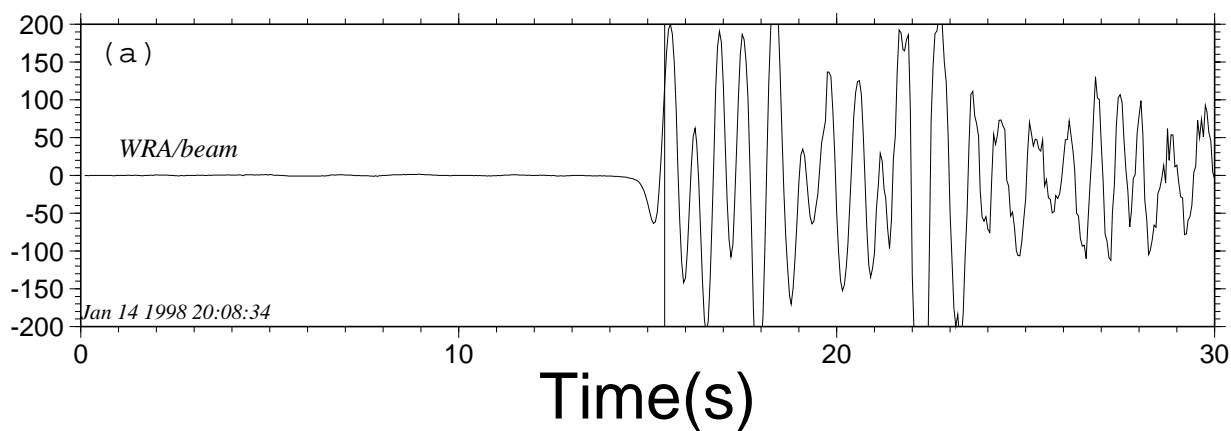


**Figure 2: Third Moment of Frequency v mb at 4 primary stations for the four 1995-1996 Chinese nuclear explosions (triangles) and earthquakes near the test site (circles). The Testbed measurements also shown, span the period: Jan 4 - Jan 20, 1998.**

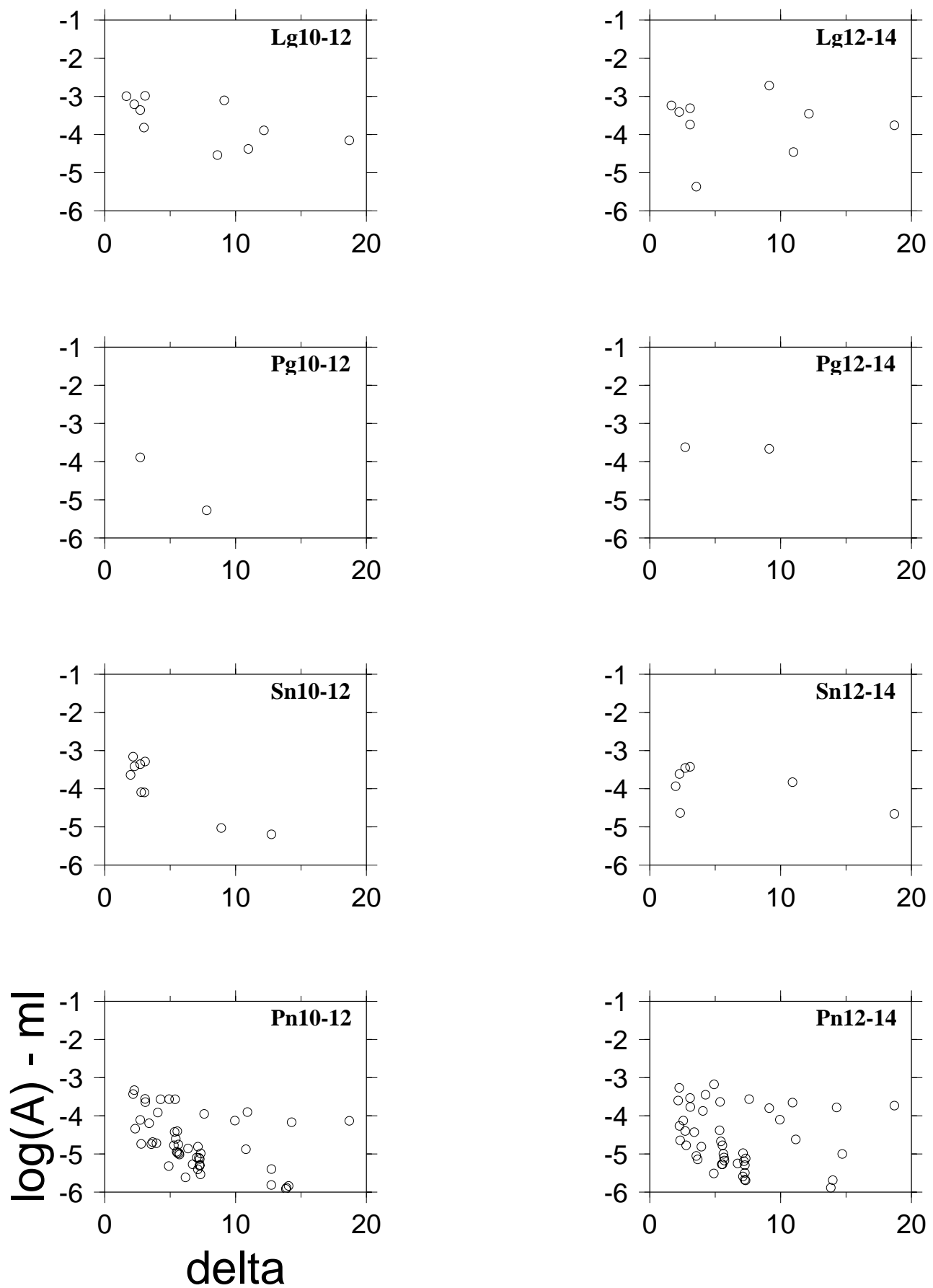


**Figure 3: zavcep, zavcor and xcor a) calculated by PIDC\_6.0 DFX on the the Testbed where the data span the period: Jan4 - Jan 20, 1998, b) of CSS Ground-Truth Database events (orids 1-25) recorded at GERES, where triangles represent quarry blasts and circles, earthquakes.**

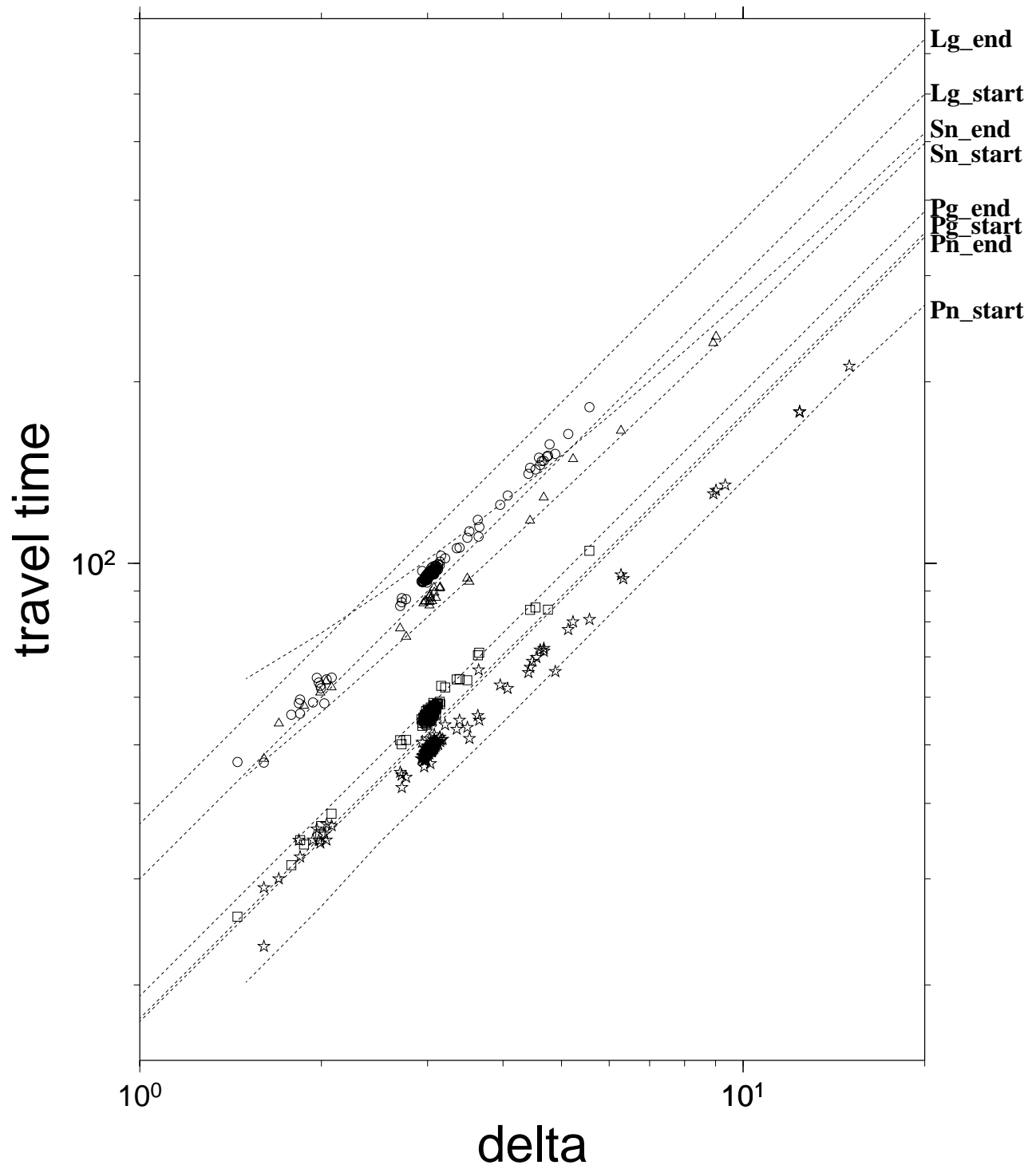




**Figure 4: (a, b) WRA beams of two well recorded events starting at the time indicated in the bottom left hand corner. The vertical line represents the onset time from the arrival table. (c) The "success" of the first motion measurement plotted against signal to noise ratio.**



**Figure 5: Plots of  $\log(\text{amplitude}) - ml$  versus distance for theoretically determined Pn, Pg, Sn & Lg, calculated by PIDC\_6.0 DFX on the Testbed, in frequency bands 10-12 and 12-14Hz, with SNR > 2. The data span the period: Jan 4 - Jan 20, 1998.**



**Figure 6:** Predicted time windows of regional phases plotted as a function of travel time versus distance, overlayen by the analyst picked MOX arrivals: Pn (stars), Pg (squares), Sn (triangles) and Lg (circles). The data span the period Sep95-May97.